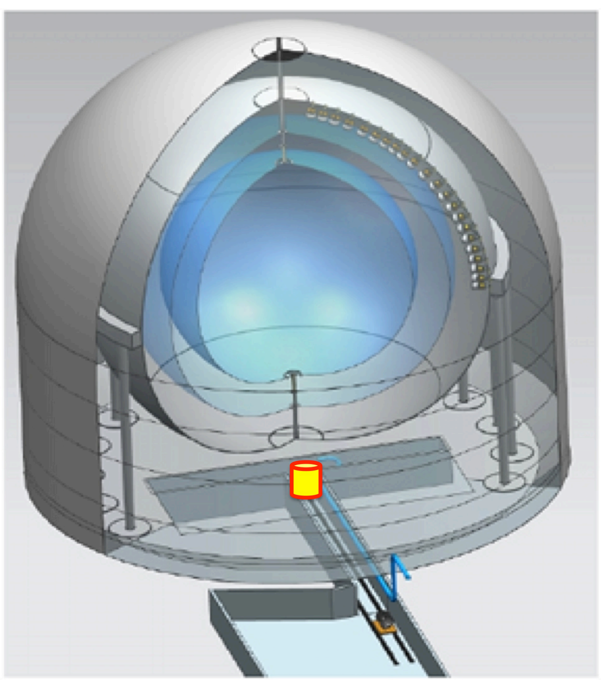
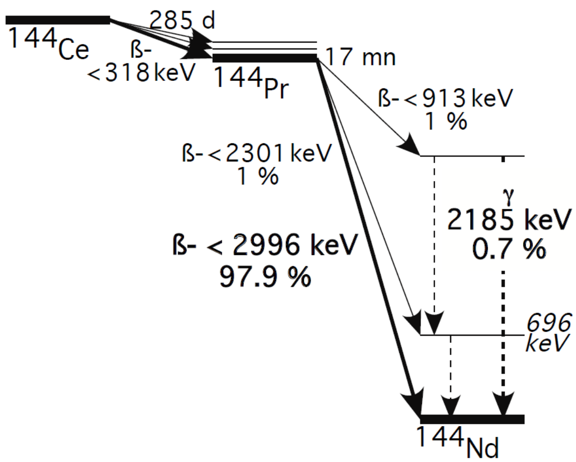
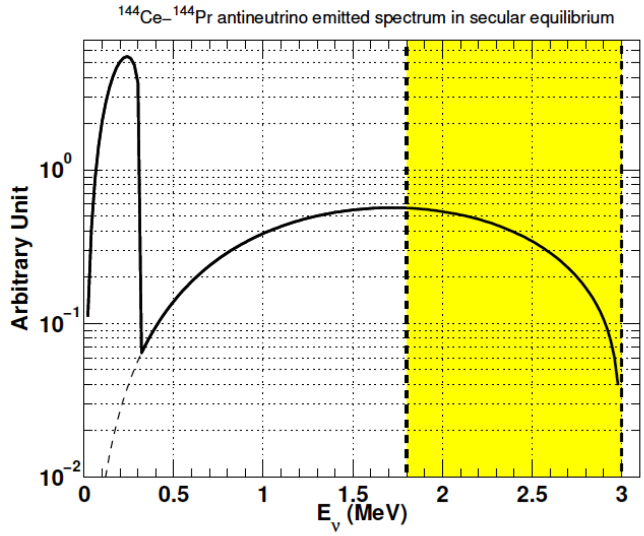
12 January 2015

1. *Name of Experiment/Project/Collaboration:* **CeSOX**
2. *Physics Goals*
   a. Primary: **Search for the very short baseline neutrino oscillations (less than 10 m) and 4th neutrino species in the mass range around 1 eV and independent cross-check of sterile neutrino hints coming from reactors (Reactor Antienutrino Anomaly).**
   b. Secondary: **By combining the electron neutrino – electron data from ^{51}Cr source and electron antineutrino - proton data from 144Ce-144Pr source, the vector (g_V) and axial (g_A) current coefficients of the low energy Fermi current-current interaction can be measured.**
3. *Expected location of the experiment/project:* **Borexino detector in the Gran Sasso national laboratory in Italy; more specifically, small access space under the Borexino detector, 8.25 m from the detector center. The figure below shows Borexio detector with the blue inner nylon vessel defining scintillator, target volume and neutrino source depicted with yellow cylinder below the detector.**

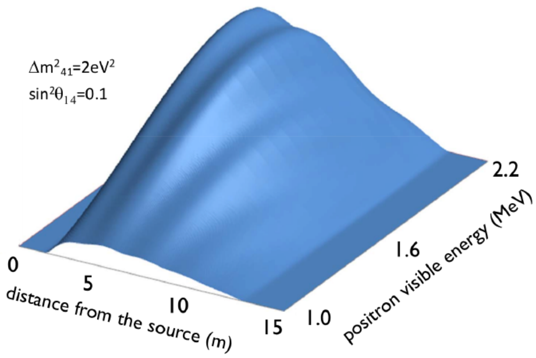


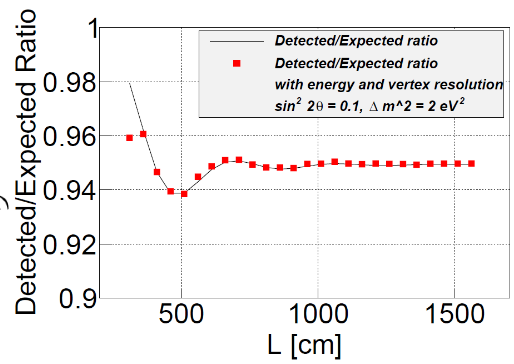
4. *Neutrino source:* **Antineutrino generator ^{144}Ce-^{144}Pr double beta decay radioactive source with strength of up to 5.5 PBq activity producing electron antineutrino spectrum with endpoint at 3 MeV shown in the figure below.**





5. *Primary detector technology:* **Borexino is a 300 ton liquid scintillator calorimeter, with PMTs mounted on the walls to detect scintillation light from energy depositions from particle interactions.**
6. *Short description of the detector:* **Borexino is a long-term running solar neutrino detector with very low energy threshold and very low backgrounds that can easily detect electron antineutrinos via inverse beta decay and energy threshold of 1 MeV visible energy in the detector. Thus, Borexino is well suited to detect electron antineutrinos from the cerium antineutrino generator described above. Large size of Borexino will allow detection of antineutrinos with baseline from 4 to 12 m with excellent energy resolution (6%/sqrt(E[MeV]) and excellent position resolution of 9 cm and better at higher energies. Such excellent energy and position resolution, combined with negligible backgrounds will provide excellent condition to measure distance dependent flux and spectrum and detect oscillation pattern in case of sterile neutrino oscillations.**





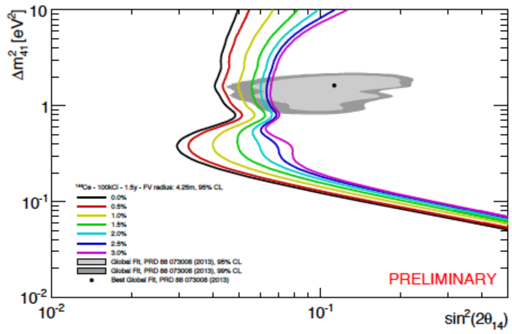
7. *List key publications and/or archive entries describing the project/experiment:* **Borexino website at** *http://borex.lngs.infn.it/* **lists all Borexino publications. The publication specifically describing SOX for both cerium and chromium phase is:**

arXiv:1304.7721v2 (or Journal of High Energy Physics, 2013:38, August 2013 [doi:10.1007/JHEP08(2013)038]

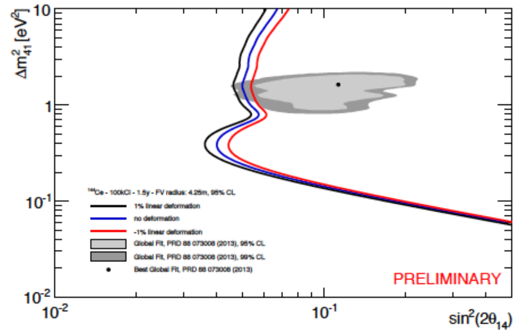
8. *Collaboration*
   a. *Institution list:* **Several Italian, French, German, Spanish, Russian, Polish, Ukraine and US institutions (list available in arXiv:1304.7721v2). Participating US institutions are: Princeton University, Virginia Tech, University of Hawaii, University of Houston, University of Massachusetts.**
   b. *Number of present collaborators:* **slightly over a 100**
   c. *Number of additional collaborators needed:* **new collaborators are welcome, no upper limit specified as long as the contribution is important to the experiment.**
9. *R&D*
   a. *List the topics that will be investigated:* **detailed measurement of the 144Pr beta spectrum, absolute activity of the radioactive source with calorimetric method, alternative measurements of the source activity, contamination of the source with neutron producing isoptopes.**
   b. *Which of these are crucial to the experiment:* **Both detailed ^{144}Pr beta spectrum and precise measurement of the activity of the source are**

crucial to maximize the experimental yield. This is illustrated by the figures below.

Source activity uncertainties:



Energy distribution uncertainties:



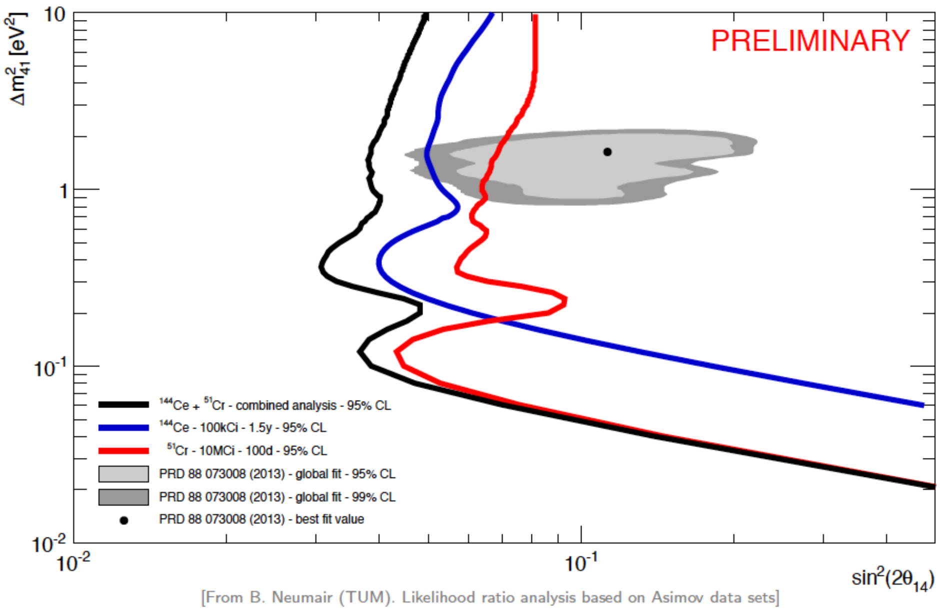
c. *Time line:* **Both beta spectrum and activity measurement with calorimeter are planned for 2015, prior to source deployment. However, beta spectrum measurement of the samples can continue and source activity will be measured again at the end of the deployment.**

d. *Benefit to future projects:* **precise knowledge of ^{144}Pr beta spectrum is of general interest. Techniques in achieving 1% precision in calorimetric source activity are important. Finally experience with building 2.2 ton tungsten shield, production, transportation and handling of the highly radioactive source are important for future similar experiments.**

10. *Primary physics goal expected results/sensitivity:*

a. *For exclusion limit (such as sterile neutrino search), show 3-sigma and 5-sigma limits:*

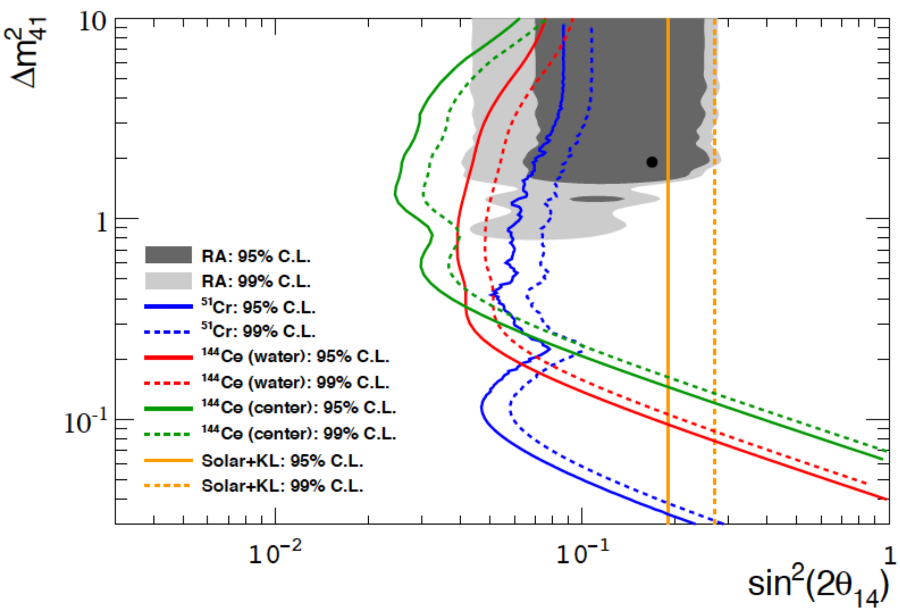
CeSOX in combination with Chromium SOX have unique approach to searching for sterile neutrinos, free of systematics related to reactors or accelerators. Figure below shows the sensitivity potential of cerium and chromium source. CeSOX will be mostly limited by the statistics as the source strength is significantly decreased after 1.5 years. Nevertheless, CeSOX will provide clean measurement and in the case of a positive signal, the second source could be deployed within another year to investigate whether the positive signal is due to oscillations.



[From B. Neumair (TUM). Likelihood ratio analysis based on Asimov data sets]

b. *For discovery potential (such as the Mass Hierarchy), show 3-sigma and 5-sigma.* **See figure above.**

c. *For sensitivity plots, show 3-sigma and 5-sigma sensitivities:***.**



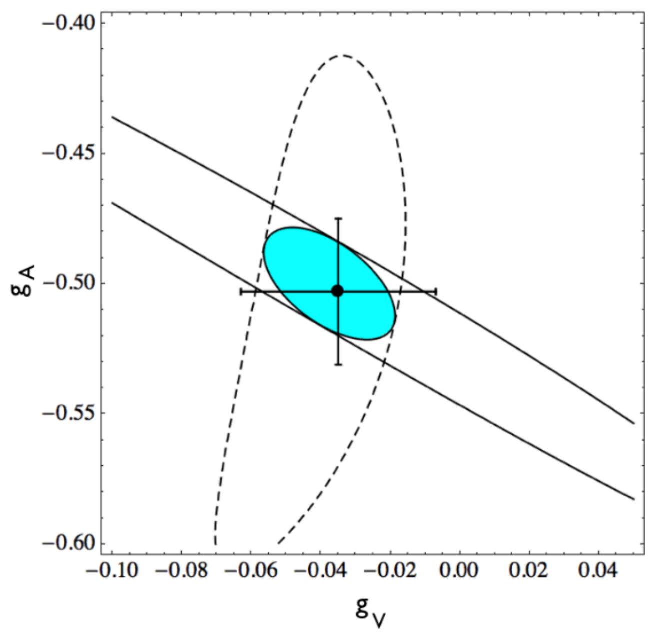
d. *List the sources of systematic uncertainties included in the above, their magnitudes and the basis for these estimates:* **Fiducial volume (1%), energy resolution (6%/sqrt(E[MeV})) and position reconstruction (9 cm), source activity uncertainty (1.5%) and overall experimental systematic error (2%).**

e. *List other experiments that have similar physics goals:* **Ce and Cr SOX is unique in the entire world in terms of method used to search for sterile**

neutrinos. A number of reactor experiments and some accelerator experiments have the same physics goal.

11. *Secondary Physics Goal*

   a. *Expected results/sensitivity:* **SOX can provide the best measurement of g_V – gA at lower energies which is particularly interesting as this the range where there is a better chance to probe non-standard neutrino interactions (since Fermi interaction increases with energy).**



   b. *List other experiments that have similar physics goals:* **None.**

12. *Experimental requirement:*

   a. *Provide requirements (neutrino source, intensity, running time, location, space,…) for each physics goal:* **Neutrino source ^{144}Ce-^{144}Pr will be deployed for 18 months (5.5 PBq activity). This time gives a balance between the need for higher statistics and lifetime of the source (half-life of ^{144}Ce is 285 days). The source will be in the pit under Borexino for the entire period of data taking. However, in case of a positive signal it is possible to quickly add scintillator to outer nylon vessel increasing the fiducial volume 3 times.**

13. *Expected Experiment/Project time line*

   a. *Design and development:* **<1 year, underway at present.**
   b. *Construction and Installation:* **To be ready by the end of 2015.**
   c. *First data:* **End of 2015 to early 2016**
   d. *End of data taking:* **18 months after the beginning, so sometimes in 2017.**

   e. *Final results:* **Definitive results in 2017.**

14. *Estimated cost range*
   a. *US contribution to the experiment/project:* **$0.2M for tungsten shield (DOE)**
   b. *International contribution to the experiment/project:* **$4.45M**
   c. *Total:* **$4.65M**

15. *The Future*
   a. *Possible detector upgrades and their motivation:* **In case of a positive signal, the second source will be produced and placed in the detector center which will increase the statistics 5 times and provide different baseline with higher sensitivity to large sterile neutrino mass of a couple of eV**
   b. *Potential avenues this project could open up:* **A breakthrough measurement would pave the path to the next step and that is more detailed characterization of the sterile neutrino oscillations and study of the particle of the fourth generation.**